Baseline water quality, soil, periphyton, and macrophyte data from the Rotenberger Wildlife Management Area, 1998.

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INTRODUCTION

The Rotenberger Wildlife Management Area (RWMA) is a 27,810-acre parcel of land that lies atop the northwest corner of Water Conservation Area 3A (WCA-3A; Figure 1). In accordance with Everglades Forever Act and the Consent Decree between the Federal and State of Florida governments, the RWMA is targeted for hydropattern restoration. To this end, the RWMA will receive discharge from Stormwater Treatment Area 5 (STA-5), a filtering marsh designed to remove nutrients from EAA runoff before it is discharged into the Everglades (Figure 1). STA-5 is scheduled to begin operation in the year 2000. Ecosystem responses to this event will be documented as part of a long-term monitoring program implemented by the South Florida Water Management District (SFWMD) in accordance with the Army Corps of Engineers 404 permit for STA construction. Future assessments of ecological benefits and impacts caused by STA discharges will require adequate information on present conditions as a basis for comparison. This status report provides baseline information on water quality, soil, periphyton, and macrophytes in the RWMA. The applicability of these data to the Everglades Phosphorus Gradient model (Walker and Kadlec, 1996) also is discussed.

METHODS

MONITORING SITES

Two transects were established in the northwest corner of the RWMA near the point of future STA-5 discharges (Figure 1). Transects were oriented in a southeast direction towards the interior of RWMA; this orientation roughly follows an elevation gradient and, therefore, the anticipated direction of flow for discharges from STA-5.

Between November 1997 and February 1998, five 15 m-long wooden platforms were constructed at stations located along each transect at distances approximately 0.25, 0.50, 1.0, 2.0, and 4.0 km away from the point of STA-5 discharge. Stations were designated as $N_{0.25}$, $N_{0.50}$, $N_{1.0}$, $N_{2.0}$, $N_{4.0}$ for northern transect and $S_{0.25}$, $S_{0.50}$, $S_{1.0}$, $S_{2.0}$, $S_{4.0}$ for southern transect. All sampling was either conducted directly from or in the immediate vicinity of the station platforms. A schematic diagram of specific sampling locations for each measured parameter is shown in Appendix A.

WATER QUALITY

Surface-water was collected from the north (upstream) end of each platform using a peristaltic pump. A pre-screen was attached to keep out large debris and samples were taken only when water depths exceeded 10 cm in order to avoid contamination from particulate matter. Sample bottles were triple rinsed with ambient, filtered water prior to sample collection. Dissolved constituents were passed through a 0.45-µm membrane filter. Conductivity, dissolved oxygen, temperature, and pH were measured using a precalibrated Hydrolab™ Minisonde with a Surveyor 4 unit. Samples were preserved according to standard methods, sealed in plastic bags, and transported back to the laboratory on ice. Samples were shipped overnight on ice to the Florida Department of Environmental Protection (FDEP) for analysis. All field and laboratory methods adhered to approved SFWMD and FDEP protocols (FDEP, 1997).

Porewater was collected using a peristaltic pump from two 6-cm-diameter wells spaced approximately 1 m apart and located 1 m from the north end of each platforms. The wells were first purged and a small amount of this water was used to measure pH

with a portable meter. The remaining water was used to rinse each sample bottle once prior to sample collection; water volumes in the wells were insufficient to allow for triple rinsing. Wells were allowed to recharge for approximately 5 min. Samples were collected by passing water through a 0.45-µm membrane filter. Samples were stored and processed as for surface-water samples.

A list of surface-water and porewater parameters and analytical methods is provided in Table 1.

SOILS

Soils were sampled within specific vegetation types. In this regard, macrophyte communities at most stations were spatially heterogeneous, and *Cladium jamaicense* (sawgrass) and *Typha domingensis* (cattail) generally existed as visually distinct patches or stands within a mosaic of other community types. Specific areas to the east and/or west of the station platforms were selected that could be classified as either *Typha domingensis*-dominated, *Cladium jamaicense*-dominated, or non-*Cladium*/*Typha* communities (termed "mixed-meadows"). Reference poles were placed within these stands, and soils were sampled by walking out approximately 2 to 3 m north, west, and south from the poles to obtain triplicate samples. An additional *Typha* site near $N_{0.50}$ was included in the sampling regime that was not used for macrophyte collections.

A 10-cm-diameter aluminum coring tube was placed on the soil surface and a serrated knife was used to cut around its circumference as a means to avoid soil compaction during core insertion. Cores were extruded and sectioned into 0-2, 2-10, and 10-20 cm depth layers. Samples were sealed in plastic bags, immediately placed on ice,

and shipped overnight to an outside contract laboratory (DB Laboratories, Rockledge, FL) for various analyses (Table 1) according to the procedures of ASA 1982, Page et al. (1982), USEPA (1983), COE (1986), and Reddy et al. (1991).

Soil accretion - In March 1998, three 0.25m^2 quadrats were inoculated with feldspar at stations $S_{0.25}$ and $S_{4.0}$ to mark the location of the sediment surface for soil accretion estimates. With calipers, accretion was measured as the thickness of soil above these feldspar marks. Sediment Elevation Tables (SET), which measure soil erosion and accretion based on an initial measurement, could not be established at these stations due to the shallow peat depth (a new, smaller SET apparatus is currently being fashioned and will be established in the spring of 1999). Accordingly, 5/16" stainless steel pins were inserted into the soil to obtain similar data.

PERIPHYTON

Periphyton was collected from mixed-meadow communities where macrophyte biomass is low and, consequently, light penetration is high. Triplicate samples were collected by locating sites in the same manner as for soils (see Appendix A). Each sample consisted of material harvested within a 0.25m^2 plot delineated by a PVC frame.

Periphyton and associated macrophyte biomass – Periphyton biomass harvests were conducted at all stations during October, 1998. An earlier dry season harvest scheduled for April, 1998 was cancelled as no surface-water was present in RWMA at that time. Plots for harvesting were selected as previously described. Above-water macrophyte

vegetation within each plot was first clipped and bagged. Free-floating periphyton (i.e., metaphyton), when present, was then collected and sealed in plastic bag. Finally, all submerged, rooted vegetation and associated periphyton (i.e., epiphyton) was removed by clipping at the soil-water interface and sealed in a separate plastic bag. Benthic periphyton (epipelon) was not present at any station during the sampling period. Samples were transported back to the laboratory on ice and refrigerated at 4^{o}C until processing could be completed. Periphyton material in each sample was manually separated from associated macrophyte material and then homogenized in deionized water. Quantitative subsamples were dried at 105°C for approximately two the three days to achieve a constant weight, and this dry weight was recorded. Dried material was then ashed in a muffle furnace for one hour at 500°C and weighed to calculate ash-free dry weight (AFDW), which is the total amount of organic material (i.e., periphyton material) in the sample. Total AFDW for the sample was calculated based on the proportion of material processed and expressed on an area basis (g/m^2).

Primary productivity - Light/dark bottle incubations were used to measure rates of photosynthesis and respiration. On October 12, 1998, the dominant periphyton type (epiphyton) was collected from each station in the vicinity of the biomass harvest sites, sealed in plastic bags, and transported to the laboratory in a cooler at ambient temperature. Visually similar amounts of each sample were placed in six biological oxygen demand (BOD) bottles filled with surface-water collected from an oligotrophic region in Water Conservation Area 2A (WCA-2A). A common source of incubation water was used for practical and logistical reasons since water quality has little influence

on production rates over the short incubation times (1 to 2 hr) required to obtain these measurements (McCormick, unpublished data).

Bottles were sealed without trapping oxygen bubbles, and three of the bottles were wrapped in foil to block light, thereby inhibiting photosynthesis. These bottles were used to measure respiration only. The remaining three bottles were left uncovered to measure net primary production (NPP), which includes both photosynthesis and respiration. Light and dark bottles filled with water but containing no periphyton also were included in the incubation to account for water-column metabolism. Bottles were incubated outside in a large circular tub filled with tap water at a temperature of ~ 28°C. The incubation tub was covered with neutral-density shade cloth that reduced irradiance to ~50% to order to prevent photoinhibition. Photon flux was monitored continuously and incubations were terminated when a predetermined quantity of light (~5 mol m^{-2}) had been received. Initial and final dissolved oxygen (DO) concentrations were measured for each bottle to using a calibrated, polarographic oxygen probe to estimate photosynthetic (oxygen production) and respiration (oxygen consumption) rates. Periphyton in each bottle was processed as described above to determine AFDW. Net primary productivity (light bottles) and respiration (dark bottles) were calculated as described by McCormick et al. (1998) based on rates of change in DO (corrected for water-column metabolism) in relation to the quantity of periphyton (AFDW) and quantity of light received over the incubation period.

Tissue nutrients - Approximately 10 g (wet weight) of the dominant periphyton type (generally epiphyton) was collected at each station in the vicinity of the biomass harvest

sites, sealed in a plastic bag, and transported back the lab in an ice-filled cooler. The samples were then shipped to DB labs for analysis of total carbon (TC), total nitrogen (TN), and total phosphorus (TP) using standard methods.

Taxonomy - One to two grams (wet weight) of periphyton were separated out from the tissue nutrient samples and placed in a centrifuge tube with approximately 10 to 14 ml of deionized water. Samples were preserved in formaldehyde (3.7% v:v). Samples were shipped to FDEP for determinations of species composition and abundance.

Periphytometers - On October 8, 1998, four periphytometers, each consisting of a rack of 8 glass slides, were deployed at stations with sufficient surface-water ($N_{0.50}$, $N_{1.0}$, $N_{2.0}$, $N_{4.0}$). Previous attempts to deploy periphytometers on a quarterly basis were unsuccessful due to insufficient surface-water at all stations. Periphytometers were tethered to a PVC pole near the north end of each station. On December 17, 1998, the colonized slides were removed from the rack, sealed in a plastic bag, and transported to the laboratory on ice. Periphyton was scraped from the slides and homogenized in deionized water. Quantitative subsamples were removed to measure chlorophyll *a* and AFDW, and for taxonomic analysis.

Chlorophyll *a* samples were preserved using a small amount of $MgCO_3$ and frozen. Nine ml of acetone were added to one ml of preserved periphyton sample and mixed thoroughly in a centrifuge tube. The tubes were then sonicated in an ice bath for 60 minutes and allowed to steep at 4°C in the dark for 24 hours. Samples were then allowed to equilibrate to room temperature and centrifuged at 3500 rpm for 12 minutes.

Chlorophyll and phaeopigment concentrations were then determined fluorometrically. Ash-free dry weights were determined as described above. Taxonomic samples were preserved with 3.7% formaldehyde and shipped to FDEP for analysis.

MACROPHYTES

Macrophyte biomass - Sampling locations were determined in a manner similar to soil and periphyton sampling (Appendix A) but were limited to *Cladium* and *Typha* stands. At station $N_{0.25}$, two different *Cladium* stands were identified corresponding to short (recently burned; $N_{0.25s}$) and tall plants (undisturbed; $N_{0.25t}$). All aboveground macrophyte biomass (AGBIO) was harvested within 0.25 m^2 plots delineated by a PVC frame. Soil within the plot was then collected to a depth of 30 cm (Miao & Sklar, 1998) to include belowground plant components (BGBIO). Samples were transported back to the laboratory in large plastic bags for processing. Each sample was separated into dominant (*Cladium* or *Typha*) and non-dominant species (i.e. other than *Cladium* or *Typha*). Plant material of the dominant species was further separated into live vs. dead aboveground (shoots/leaves) and belowground (live and dead) parts. Above- and belowground material of non-dominant species was processed as a single component (AG&BGBIO). After processing, biomass samples were placed in large paper bags, dried at 80°C for two weeks, and weighed to determine total dry weight.

Plant/leaf densities and heights - Permanent 0.25 m^2 plots were established at locations approximately 5 m to the north, east or west, and south of the reference poles within the designated *Cladium* and *Typha* stands (Appendix A). Two opposite corners of each plot

were demarcated with lengths of conduit around which a 0.5 m x 0.5 m (0.25 m^2) quadrat could be fit during analysis. Within the plots, the number of plants of each individual species was quantified. Plants were identified according to Godfrey and Wooten (1979), Bell and Taylor (1982), and Tobe (1998). For *Cladium* and *Typha*, whose leaves arise from a shoot base or culm, the number of both live and dead attached leaves also was recorded. For prostrate species, such as *Ludwigia repens*, a percent cover was estimated. This species was excluded from estimates of plant density due to the difficulty of counting the extremely small individual stems that characterize this ground-cover-type plant. Additionally, this species, when present, comprises a very small proportion of overall plant biomass. The heights of 10 randomly selected leaves of the dominant vegetation (*Cladium* or *Typha*) were recorded in these same plots. If less than 10 leaves were present within the quadrat, additional leaves adjacent to the plot were used.

Tissue nutrients - Small subsamples (3 to 4 grams dry weight) were taken from each separated component (live leaves, dead leaves, roots) collected during the biomass harvest, sealed in plastic bags, and shipped to DB labs for analysis of TC, TN, and TP.

General species diversity and species habitat classifications - Documentation of overall species diversity was conducted at a larger spatial scale by visual inspection of all submerged and emergent plant species occurring within ~10 m of the station platforms. This inventory was conducted over an eight-month period between March and October 1998. This extended period of observation was necessary because some species can only be identified by their inflorescences or seed heads, which are present only during certain

times of the year. Plant communities were further characterized by calculating the total number of plants (all species) and percentages of those species classified as obligate wetland (OBL), facultative wetland (FACW), facultative (FAC), or upland (UPL) (Tobe et al., 1998). These classifications are listed in the order of decreasing tolerance to inundation.

Vegetation transects - In order to assess whether relationships existed between water levels, soil depths, and macrophyte community type, a number of 50 m line-transects were established through areas in which the dominant vegetation clearly transitioned from *Cladium* to *Typha*. The line-transect locations were scattered around the entire Rotenberger tract as well as near several monitoring stations (Table 2). The dominant macrophyte species was recorded at 2-m intervals along each transect. Water depths were measured at each interval with a meter stick. Soil depths were determined by hammering a piece of rebar down to the underlying bedrock.

MODELING

Overview of model - The Everglades Phosphorus Gradient Model (EPGM) developed by Walker and Kadlec (1996) is a tool for evaluating the impact of STA discharges on receiving areas. The model simulates surface-water and soil P concentrations based on a first-order P settling rate and *Typha* density based on an empirical relationship between *Typha* density and soil P concentration. The model was originally calibrated using data from WCA-2A. It has not been calibrated for other areas due to insufficient data.

We analyzed the soil P and vegetation data from the RWMA and attempted to use them to recalibrate the EPGM for the RWMA. When sufficient data exist, there are generally three components in the EPGM that can be calibrated to specific areas in which the model is applied. These components include: (1) P net settling rate; (2) the relationship between soil accretion rate and P accretion rate, and: (3) the relationship between *Typha* density and soil P concentration. Currently, the hydrology of the RWMA can be described as rainfall-driven without structure inflow from its boundaries. There are no obvious P gradients within the monitoring area such as that observed south of S-10 structures in WCA-2A. Consequently, the P net settling rate parameter cannot be calibrated until the STA-5 is in operation, which may generate a P gradient along the flow path. Furthermore, the calibration of the relationship between soil and P accretion rates is not possible because it requires long-term soil accretion data that are not available at this time. We therefore concentrated our efforts on the analysis of soil TP concentration data and vegetation coverage to assess whether they can be used in the model recalibration.

Data description - The soil TP data that were collected at three depth intervals (0-2, 2-10, 10-20 cm) were integrated into 0-10 cm and 0-20 cm intervals for the EPGM. Soil TP concentrations at the 0-20 cm interval are believed to better represent the vegetation response as this depth includes most of the root biomass (Walker and Kadlec, 1996). The equations to integrate soil TP concentrations are as follows:

$$TP_{0-10} = \frac{2TP_{0-2}D_{0-2} + 8TP_{2-10}D_{2-10}}{2D_{0-2} + 8D_{2-10}}$$

$$TP_{0-20} = \frac{2TP_{0-2}D_{0-2} + 8TP_{2-10}D_{2-10} + 10TP_{10-20}D_{10-20}}{2D_{0-2} + 8D_{2-10} + 10D_{10-20}}$$

(TP is the soil TP concentration in mg/kg and D is the soil bulk density in g/cm^3. The subscripts indicate the depth interval in cm).

STATISTICAL ANALYSES AND DATA PRESENTATION

Water quality constituents were examined by two-way ANOVA (Statistica ver. 4.5) with station and month as principal sources of variation while periphyton, macrophyte biomass, tissue nutrients, and soil data were compared among sampling locations (station) and species (*Cladium*, *Typha*, mixed-meadows). All data were initially tested for homogeneity of variances. Heteroscedasticity, when present, was eliminated or substantially reduced by log-transformation, although values are presented graphically as original, untransformed values with standard error bars. ANOVA probabilities (P_{st} = station, P_t = time, P_{mp} = macrophyte species or community-type, $P_{st\text{-}saw/cat}$ = *Cladium* (saw) or *Typha* (cat) -pooled stations) of equal means are included in the upper corners of the graphs. Any specific comparisons among individual means were done using Tukey's honest significant difference tests. Linear regression analysis was used to determine relationships between water and soil depths from the line-transect data. Station-pooled means (within separate macrophyte community-types where applicable) and standard errors for each measured parameter are indicated in parentheses in the text.

RESULTS

Water depths at the majority of transect stations were very low and further diminished by persistent dry weather over the summer months of 1998. Accordingly, the collection of water quality data was limited. Data collected from a CR-10 recorder at station $N_{4.0}$ indicates that water levels in the RWMA declined rapidly (accompanied by a rise in water temperature) beginning in April 1998 (~Julian day 120; Figure 2a, b). Data recording by the CR-10 ceased from Julian day 225 to 227 due to excessively low water levels. Most of the higher-elevation, southern transect stations remained dry until October. The lower-elevation northern transect stations began to accumulate surface-water in September. Figure 2c portrays station elevations relative to one another as depicted by a water depth profile obtained at each station during December 1998 after ground water wells had been inserted to record subsurface-water levels. Surface-water could be sampled at stations $N_{0.50}$, $N_{1.0}$, $N_{2.0}$, $N_{4.0}$, and $S_{4.0}$ in September only. Porewater was obtained from stations $N_{0.25}$, $N_{0.50}$, $N_{1.0}$, $N_{2.0}$, $N_{4.0}$, and $S_{4.0}$ in March and from $N_{4.0}$ and $S_{4.0}$ in September.

SURFACE-WATER

Abbreviations used for water quality constituents are listed in Table 1. Station-pooled means and standard errors are given in parentheses in the text.

Alkalinity, conductivity, dissolved oxygen, dissolved organic carbon, and pH - Alkalinity (measured as $CaCO_3$ concentration; Figure 3a) and DOC (Figure 3d) concentrations

averaged over all stations were 188.2 ± 26.3 mg/L and 42.4 ± 5.82 mg/L, respectively. Levels of these constituents were nearly twice as high at $N_{0.50}$ compared to all other stations (Figure 3a,b). As reliable conductivity (257 ± 68 uhos/cm, Figure 3b), DO (3.79 ± 0.73 mg/L, Figure 3c), and pH (6.86 ± 0.04; data not shown) readings could only be obtained at two stations, no spatial gradients could be determined.

Nutrients – Surface-water analysis revealed elevated concentrations of NH_3 (0.12 ± 0.67 mg/L; Figure 4a), TKN (2.60 ± 0.47 mg/L; Figure 4b), and TKN-F (2.86 ± 0.48 mg/L; Figure 4c) at the $N_{0.50}$ station. Concentrations at other stations were consistently low. NO_x was undetectable except at $N_{0.50}$ (Figure 4d). TP (0.018 ± 0.004 mg/L; Figure 4e), TPF (0.012 ± 0.003 mg/L; Figure 4f), and PO_4 (0.007 ± 0.001 mg/L; Figure 4g) exhibited similar spatial trends among stations. SiO_2 (Figure 4h) was variable with a range of 8.7 ($N_{0.50}$) to 1.7 ($N_{2.0}$) and a station-averaged value of 5.80 ± 1.29 mg/L. K (0.29 ± 0.07 mg/L; Figure 4i) ranged from 0.14 mg/L at $S_{4.0}$ to 0.53 mg/L at $N_{0.25}$ (Figure 5e). NO_2 was undetectable at all stations (data not shown).

Metals and other major ions - Fe concentrations generally were very high (496.8 ± 87.1 μg/L; Figure 5a) with a maximum of 801 μg/L at station $N_{0.50}$. Mg (5.53 ± 0.67 mg/L; Figure 5b), Zn (4.12 ± 1.2 μg/L; Figure 5c), and Ca (75.5 ± 11.2 mg/L; Figure 5d) also were elevated at $N_{0.50}$ compared with other stations. In contrast, Na varied little among stations (6.28 ± 0.43 mg/L; Figure 5e) and Cu was never above detection (not shown). Cl (11.2 ± 0.37 mg/L; Figure 5f) was low with a narrow range of 10-12 mg/L while SO_4 (2.64 ± 1.31 mg/L; Figure 5g), generally was low except at $N_{0.50}$.

POREWATER

pH and dissolved organic carbon - Porewater pH averaged 6.70 ± 0.06 over all stations in March and increased to 7.14 ± 0.06 in September (Figure 6a). DOC averaged 34.5 ± 3.4 mg/L in March and increased to 61.5 ± 6.0 mg/L in September (Figure 6b).

Nutrients - NO_x concentrations were similar among most of the stations in March (0.058 ± 0.03 mg/L; Figure 7a). At $N_{0.25}$, however, NO_x was approximately tenfold higher. Concentrations rose significantly at the $S_{4.0}$ station in September. NH_3 averaged over all stations in March was 0.334 ± 0.097 mg/L with a maximum occurring at $S_{4.0}$ (Figure 7b). NH_3 increased significantly at $N_{4.0}$ and $S_{4.0}$ in September. Concentrations of TKN exhibited a similar pattern among stations and over time (Figure 7c). Mean TKN concentrations were lower in March (2.6 ± 0.37 mg/L) than in September (6.5 ± 2.45 mg/L) with high values occurring at $N_{4.0}$ and $S_{4.0}$. TP was quite variable with maximum and minimum values occurring at $N_{0.25}$ and $N_{2.0,}$ respectively (Figure 7d). TP averaged over all stations was 0.013 ± 0.004 mg/L. PO_4 was consistently low in March (Figure 7e), but rose sharply in September ($N_{4.0}$ and $S_{4.0}$ stations only). Potassium (K), varied considerably among stations but generally was low (Figure 7f). The mean K concentration in March was 0.358 ± 0.062 mg/L with no appreciable increase at $N_{4.0}$ and $S_{4.0}$ in September.

Metals and other major ions - Fe concentrations were extremely high at all stations with a mean value of 1210 ± 375 μg/L and a range of 325 ($N_{2.0}$) to 4490 μg/L ($N_{4.0}$) (Figure

8a). Variability between the two porewater wells also was quite high for this parameter at some stations. Along the transects, Fe was highest at the most interior stations ($N_{4.0}$ and $S_{4.0}$) of each transect, and were similar in March and September. Mg was generally low among stations in March (5.4 ± 0.64 mg/L; Figure 8b) with a moderate increase at $N_{4.0}$ and $S_{4.0}$ in September. Ca concentrations in March generally were similar among stations (78.98 ± 7.76 mg/L; Figure 8c) and increased slightly in September. Cl averaged 6.5 ± 0.37 mg/L in March and increased to 9.5 ± 1.3 mg/L in September (Figure 8d). SO_4 concentrations were high at the $N_{0.25}$ and $N_{0.50}$ stations compared to those further along the transect (Figure 8e). Like many of the other constituents, SO_4 concentrations were greatly elevated in September (compared to March) at the $N_{4.0}$ and $S_{4.0}$ stations.

SOILS

0-2 cm layer - Bulk density (BD) did not vary significantly among stations and was only slightly higher under mixed-meadow (0.416 ± 0.022 g/cm^3) vegetation compared to *Typha* (0.313 ± 0.054 g/cm^3) and *Cladium* (0.319 ± 35 g/cm^3) which were similar to each other (Figure 9a). Soil TP concentrations were nearly identical under *Typha* (603 ± 71 mg/kg) and *Cladium* (612 ± 100 mg/kg) and were lowest under the mixed-meadow (447 ± 61 mg/kg) communities (Figure 9b). Among stations, TP was highest at $N_{0.50}$. On a bulk density basis, TP was slightly higher at $N_{0.50}$ and exhibited similar values among all three macrophyte stand types (Figure 9c). Soil TN (Figure 9d), and TC (Figure 10a) displayed similar patterns. Ca showed some differences among stations with high concentrations at $N_{0.50}$ and minimums at $S_{1.0}$ but no differences existed among *Cladium* (27476 ± 3578 mg/kg), *Typha* (35083 ± 6573 mg/kg), or mixed-meadow (25883 ± 3810 mg/kg)

communities (Figure 10b). %Ash varied significantly among stations, although no clear trends along the transects were evident (Figure 10c). % Ash was only slightly less in *Cladium* (32.5 ± 3.4%) than in *Typha* (39.7 ± 5.5%) or mixed-meadow communities (37.4 ± 4.3%). KCL-SRP exhibited a clear maximum at $S_{4.0}$ under *Cladium* and was higher in *Cladium* (0.186 ± 0.073 mg/kg) than either *Typha* (0.048 ± 0.015 mg/kg) or mixed-meadows (0.85 ± 0.018 mg/kg) (Figure 11a). NaOH-SRP was highest at $N_{0.50}$ but similar among macrophyte community types (Figure 11b). NaOH-TP (Figure 11c) was statistically similar among stations and macrophyte types. Soils from *Cladium* (21.4 ± 3.9 mg/kg) and *Typha* (22.5 ± 3.0 mg/kg) stands were similar to each other with respect to HCL-TP, but were significantly higher than mixed-meadows (13.4 ± 2.3 mg/kg) (Figure 11d).

2-10 cm layer - Concentrations of soil constituents in the 2-10 cm layer generally were much lower than in the 0-2 cm layer. BD varied significantly among stations but not among macrophyte types (Figure 12a). Highest TP concentrations occurred at $N_{0.50}$ but did not differ among *Typha* (434 ± 81 mg/kg) and *Cladium* (434 ± 70 mg/kg) soils (Figure 12b). Mixed-meadow TP, however, was significantly lower at 339 ± 54 mg/kg. TP (bulk-density-corrected) was higher at $N_{0.50}$ and under *Typha* (125 ± 13 ug/cm^3) and *Cladium* (128 ± 15 ug/cm^3) stands compared to mixed-meadows (88 ± 14 ug/cm^3). However, variability was high among replicates, and the difference was not significant (Figure 12c). TN (Figure 12d), TC (Figure 13a), Ca (Figure 13b), and %Ash (Figure 13c) generally were highest at $N_{0.25}$ and $N_{0.50}$, lowest at $N_{2.0}$, and were higher under *Cladium* and mixed-meadows than under *Typha*. KCl-SRP (Figure 14a) and NaOH-TP (Figure 14c) were not

significantly different among stations or macrophyte types. NaOH-SRP (Figure 14b) and HCL-SRP (Figure 14d) did show some differences among stations. Specifically, NaOH-SRP was maximal at $N_{0.50}$ under *Cladium*. Among macrophyte types, NaOH-SRP was highest under *Cladium* (31.6 ± 2.5 mg/kg), slightly lower under *Typha* (26.5 ± 4. mg/kg), and lowest under mixed-meadows (26.0 ± 4.9 mg/kg). HCL-SRP was greatly elevated at $N_{0.50}$ and was about twice as high under *Typha* (26.6 ± 9.7 mg/kg) than under *Cladium* (12.7 ± 3.9 mg/kg) and more than four times higher than under mixed-meadow (6.4 ± 1.4 mg/kg).

10-20 cm layer (data not shown) - Concentrations of TP and most other constituents were significantly lower in the 10-20 cm layer than in both upper layers. Furthermore, only the HCL-TP fraction differed among macrophyte stand types. Soils from *Typha* stands (3.89 ± 0.87 mg/kg) had almost twice as much HCL-TP as *Cladium* (2.82 ± 0.42 mg/kg) or mixed-meadow (2.26 ± 0.34 mg/kg) stands, but always constituted a relatively small amount of soil TP. Station differences were detected for all constituents except KCl-SRP and NaOH-TP. In general, soils from station $N_{0.50}$ had the highest concentrations whereas stations $N_{2.0}$ and $S_{4.0}$ yielded the lowest under all three macrophyte community types.

PERIPHYTON

Periphyton development was suppressed by the absence of surface-water along both transects for much of 1998. In October, small amounts of standing water were present at $N_{1.0}$, $N_{2.0}$, $N_{4.0}$, and $S_{4.0}$, although periphyton was only found at stations $N_{1.0}$ and $N_{2.0}$.

Periphyton and associated macrophyte biomass - Epiphyton was present in all three replicate plots at station $N_{1.0}$, whereas metaphyton was found only in the 'north' and 'south' replicate plots. At the $N_{2.0}$ station only one plot contained any measurable periphyton, present as epiphyton (Figure 15a). Total periphyton biomass was higher at $N_{1.0}$ (2.9 ± 1.4 g/m^2) than $N_{2.0}$ (0.8 ± 0.3 g/m^2) where the ratio of above: below-water macrophyte biomass was significantly higher (Figure 15b). Among the sites with standing water ($N_{1.0}$, $N_{2.0}$, $N_{4.0}$, $S_{4.0}$), periphyton was found only at those with < 500 g/m^2 total above- ground macrophyte biomass (Figure 15c).

Primary productivity – Epiphyton gross primary productivity (Figure 15d) was significantly higher in samples collected from $N_{1.0}$ (10.916 mg $O_2 \cdot hr^{-1} \cdot g^{-1}$) than $N_{2.0}$ (2.864 mg $O_2 \cdot hr^{-1} \cdot g^{-1}$). This pattern was consistent with the greater periphyton biomass at $N_{1.0}$.

Tissue nutrients - Tissue P (Figure 15e) was 695 and 620 mg/kg in periphyton harvested from $N_{1.0}$ and $N_{2.0}$, respectively. Tissue N and C were different in that $N_{2.0}$ periphyton concentrations (TN=27600 ± 850 mg/kg, TC=423666 ± 14723 mg/kg) were higher than $N_{1.0}$ (TN=22166 ± 1596 mg/kg, TC=365000 ± 5131 mg/kg).

Periphytometers - Periphyton grew at all N-transect stations except $N_{0.25}$ (where water subsidence left the periphytometer on dry ground). Periphyton accumulation on the slides averaged 0.15 ± 0.07 mg/cm^2 among stations with a range of 0.029 at $N_{4.0}$ to 0.186

mg/cm^2 at $N_{0.50}$ (Figure 16a). Chlorophyll *a* on an area basis ranged between 14 ($N_{4.0}$) and 92 ($N_{0.5}$) mg/m^2 for those sites where periphyton was present (Figure 16b).

Taxonomy – Samples for taxonomic analyses have been shipped to FDEP, but no data are available at this time.

MACROPHYTES

Biomass - Total aboveground biomass of dominant macrophytes (*Cladium* or *Typha*; Figure 17a) was extremely variable among stations for both *Cladium* (1137 ± 281 g/m^2) and *Typha* (690 ± 315 g/m^2), and no significant differences in station-averaged values existed between the two macrophyte types. Live aboveground biomass (Figure 17b), however, did differ significantly between the two, averaging 485 ± 99 and 170 ± 35 g/m^2 for *Cladium* and *Typha*, respectively. Maximum values occurred at $N_{4.0}$ and $S_{4.0}$ for *Cladium* and at $N_{1.0}$ for *Typha*. Dead aboveground biomass estimates (Figure 17c) were fairly similar, averaging 652 ± 154 g/m^2 and 520 ± 270 g/m^2 for *Cladium* and *Typha*, respectively. In *Cladium* communities, the highest dead biomass occurred at $N_{0.25}$ and $S_{4.0}$. In *Typha* stands, dead biomass was greatest at $N_{1.0}$. The mean ratio of live/dead aboveground biomass (data not shown) of *Cladium* (0.76 ± 0.08 g/m^2) was lower than that of *Typha* (1.03 ± 0.55 g/m^2). Root biomass (Figure 17d) was very similar among stations for *Cladium* (502 ± 22 g/m^2) and *Typha* (399 ± 75 g·m^{-2}) and also between *Cladium* and *Typha*. The biomass of non-dominant plants (Figure 18a) was slightly higher within *Typha* (194 ± 52 g/m^2) compared to *Cladium*-dominated (179 ± 26 g/m^2) communities. Total biomass (both dominant and non-dominant macrophytes, Figure

18b) was maximal (2670 ± 735 g/m^2) in the *Cladium*-dominated stand at $S_{4.0}$ and, on average, was significantly higher in *Cladium* than *Typha*.

Plant densities and stand heights – The mean number of dominant plants (i.e. *Cladium* or *Typha*; Figure 19a) was significantly higher for *Cladium* (38.5 ± 3.9 plants/m^2) than *Typha* (9.8 ± 2.7 plants/m^2) stands. Live and dead leaf densities did not differ among stations for either species but did differ between them (Figure 19b,c). Furthermore, the ratio of live:dead leaves in *Cladium* (2.50 ± 0.24 leaves/m^2) plants was approximately twice that of *Typha* (1.30 ± 0.50 leaves/m^2, data not shown). Mean height measurements (Figure 19d) revealed no significant differences between *Cladium* (138 ± 14 cm) and *Typha* (122 ± 21 cm). The mean number of species per plot did not differ significantly among stations or between *Cladium* (5.1 ± 0.3 species/plot) and *Typha* (5.6 ± 0.9 species/plot) stands (Figure 20a) with a range of 4.0 species/plot at $N_{0.25}$ (*Cladium* stand) to 7.3 species/plot at $S_{4.0}$ (*Typha* stand). The latter station is characterized by the lowest leaf densities and biomass of *Typha*. The number of non-dominant plants however (Figure 20b) was significantly higher in *Typha* (33.2 ± 6.4 plants/m^2) than *Cladium* (18.0 ± 2.9 plants/m^2) stands with a range of 8.7 plants/m^2 (within *Cladium* stand) at $N_{0.25}$ to 46 plants/m^2 at $N_{1.0}$ (within *Typha* stand). Conversely, the total number of plants (all species combined; Figure 20c) was higher in *Cladium* than *Typha* stands.

Tissue nutrients - TC and TN concentrations were very similar among stations and between *Typha* and *Cladium*. TN was high in non-dominant AGBIO at $N_{0.25}$. TN was higher in live compared to dead AGBIO in both *Cladium* (10877 ± 951 mg/kg) and *Typha*

(12147 ± 1223 mg/kg). TN in BGBIO (*Cladium* = 5897 ± 244 mg/kg, *Typha* = 4662 ± 266 mg/kg) was similar among stations and species. TP, although also similar among stations (within-community-types), exhibited large differences between *Cladium* and *Typha* live AGBIO. Mean tissue P was approximately twice as high in live *Typha* AGBIO (943 ± 63 mg/kg) than in *Cladium* (481 ± 19 mg/kg) (Figure 21a). Concentrations were comparatively low and uniform in dead AGBIO (Figure 21b) among stations and between *Cladium* (186 ± 10 mg/kg) and *Typha* (166 ± 12 mg/kg). BGBIO-TP concentrations (Figure 21c) in both *Cladium* (217 ± 22 mg/kg) and *Typha* (327 ± 46 mg/kg) were similar to those of dead leaves and did not exhibit any large differences among stations. The TP of non-dominant species (Figure 21a), which included both AGBIO and BGBIO (although most of the biomass was represented by AGBIO), was relatively high within both *Cladium* (688 ± 68 mg/kg) and *Typha* (533 ± 97 mg/kg) stands. The highest TP of non-dominant plant biomass (959 ± 263 mg/kg) occurred within the *Cladium* community at $N_{0.25}$.

General inventory - We documented approximately 63 different species (all stations combined) of macrophytes in the vicinity of the monitoring stations during the spring-fall of 1998 (Appendix A). The average number of species per station was 21.2 ± 2.0 with a range of 15 ($N_{0.25}$) to 38 ($N_{0.5}$) (Figure 22a). %OBL (Figure 22b) increased along both transects toward the most interior (4.0 km) sites which corresponded with increasing water levels while %FAC (Figure 22c) exhibited the opposite trend. %FACW (Figure 22b) was highest at station $N_{0.25}$ but fairly similar among the other stations. UPL species

were only recorded at $N_{0.50}$ and $S_{0.25}$. %UPL (data not shown) represented an insignificant portion of the total number of species.

Vegetation transects - Transitions of the dominant vegetation from *Cladium* to *Typha* were clearly accompanied by increases in water depth and vice versa. Figures 23a-k depict water depths along the transects with means and probabilities (P) associated with statistical comparisons between water depths in *Typha*- vs. *Cladium*-dominated vegetation (water depths were averaged over all intervals corresponding to specific macrophyte types). Reliable soil depth data could only be obtained at 10 locations. At the other four, intermediate layers of compact sand prevented penetration to the underlying bedrock. Soil depths were variable under *Cladium* and *Typha* and were correlated in different ways with water depths (Figures 24a-j). For example, in 6 out of 10 transects where the soil was shallow enough to be measured, water and soil depths were inversely correlated. Conversely, in 2 transects water depth was positively correlated with soil depth. In two others, no correlation existed.

MODEL CALIBRATION

The integrated soil TP concentration data collected at *Cladium* and *Typha* sites at 0-10 and 0-20 depth intervals are presented in Table 3**.** The data generally show lower soil TP concentrations than other areas in the Everglades and there are no clear relationships between the vegetation type and soil TP concentrations. For example, at the 0-20 cm depth interval, the mean soil TP concentration at *Cladium* sites was 6% higher than that at *Typha* sites, while the median concentration at *Cladium* sites was 14% lower.

At the 0-10 cm depth interval, both the mean and median soil TP concentrations are actually slightly higher (1% and 3% respectively) at *Cladium* sites than at *Typha* sites. These differences are very small and are insufficient to establish any meaningful relationship.

We also plotted the TP concentrations for *Cladium* and *Typha* sites at 0-10 cm and 0-20 cm depth intervals (Figures 25a,b). Equal numbers of *Cladium* and *Typha* sites lie on both sides of median soil TP line. This indicates that there is no relationship between the soil TP concentrations and vegetation type. If such a relationship existed, the *Cladium* sites and *Typha* sites would concentrate on one side of the median line instead of being evenly distributed on both sites. We also attempted to follow the classification approach by Walker and Kadlec (1996) used in the EPGM calibration. The approach was to find a "cutoff" soil TP concentration value that results in the least classification error. When the soil TP concentration was above the "cutoff" value, the site was classified as *Typha*, otherwise it is classified was *Cladium*. The goal was to find the best "cutoff" value that results in least classification error. The data from WCA-2A used by Walker and Kadlec (1996) in the EPGM generated only 1.4% of misclassified sites. When we applied the data from the RWMA, we could not find a "cutoff" soil TP concentration value that would generate better results than 33% classification error. This error was equivalent to misclassify all the *Typha* sites into *Cladium* sites.

The results of the above analysis preclude the use of RWMA to recalibrate the logistic equation used in the EPGM that establishes relationship between *Typha* densities and soil TP concentrations. In addition, the soil TP data were collected in distinct vegetation patches. The percentage of *Typha* coverage outside a patch but within the

vicinity of the sampling station was unknown. Therefore, even a site is identified as "*Typha*", it only represents the patch from which data were collected and no percentage of *Typha* coverage information can be inferred from the greater sampling station. Data on percentage of *Typha* coverage on a larger scale are needed to calibrate logistic equation in the EPGM. However, the inability to recalibrate the EPGM at this time dose not mean that the EPGM cannot be applied to the RWMA. Once the RWMA receives STA-5 discharges, it is possible that area may develop a P gradient that would facilitate model calibration.

DISCUSSION

WATER QUALITY

Many surface-water constituents were elevated at the $N_{0.50}$ station, almost certainly as a consequence of a fire event (as evidenced by burnt *Cladium* culms and topsoil) that occurred in this area sometime during the previous year. $CaCO_3$ (ALK) concentrations were similar to what has been reported for oligotrophic areas of WCA-2A but much higher than the interior of WCA-1 whereas conductivity was more than threefold lower than WCA-2 but similar to WCA-1 (McCormick and O'Dell, 1996; McCormick et al. 1998; McCormick et al., 1999; SFWMD, 1999). Concentrations of the different nitrogen species (TKN, TKN-F, NH_3-F, NO_2-F, NO_x-F) were typical of what has been observed in both wet and dry seasons from oligotrophic areas of WCA-2A (although NH_3 can be quite variable) (McCormick et. al., 1996) but approximately twice as high as in WCA-1 (McCormick et al., 1990 status report). TP, TP-F and PO_4-P were low and representative of more oligotrophic marsh conditions at all stations except $N_{0.50}$

(McCormick and O'Dell, 1996; McCormick et al. 1998). SiO_2-F and K-F were present at levels slightly lower than WCA-1 and more than tenfold lower than WCA-2A whereas Fe-F was ~20 to 100 times higher than levels detected in WCA-1 and WCA-2A (McCormick and O'Dell, 1996; McCormick et al. 1998; SFWMD, 1999). Ca was much higher than interior WCA-1 but similar to most areas of WCA-2A and the periphery of WCA-1 (McCormick et al., 1999). Other major ions (Na-F, Cl-F, and SO_4-F) were more than an order of magnitude lower than unenriched areas of WCA-2B, -3A, and Everglades National Park (SFWMD, 1992; Richardson et al. 1992; McCormick et. al., 1998). SO4 was similar, however, to interior WCA-1 (McCormick et al., 1999).

Unlike surface-water, porewater constituents did not show elevated concentrations at station $N_{0.50}$. Instead, most analytes were relatively similar among the sampled stations and were also similar to or slightly higher than concentrations in the surface-water. There was, however, a significant increase in concentrations from March vs. September - corresponding to a period of increased precipitation and rising water levels - presumably due to a leaching of certain materials from the soil. Nutrients remained relatively low (with the exception of TP-F at the $N_{0.25}$ station) but also increased in September. Fe concentrations were extremely high, reaching a maximum of 4490 µg/L (one replicate well) at station $N_{4.0}$.

It appears that RWMA is somewhat of a unique entity with respect to water quality although elevated Fe concentrations, low pH, and low alkalinity have, at times, also been observed in WCA-1 (McCormick et al., 1999). The low ionic content of RWMA surface-water is undoubtedly due to the absence of canal discharge and to a certain extent, surface-water in the RWMA resembles rainwater (Swift and Nicholas,

1987). Thus, the chemistry of soil-water column interactions after rainfall events would appear to be an important factor determining various aspects of water quality.

SOILS

RWMA soils do not show any nutrient enrichment or well-defined gradient of soil constituents along the transect stations. In fact, on a weight basis, soil nutrient levels were present at concentrations near what is considered background levels for unimpacted Everglades regions (Newman et al., 1998). When expressed on a volume basis, however, nutrient levels are high as has been similarly documented by Newman et. al. (1998). This is a consequence of soil compaction arising from desiccation. As such, RMWA soils have bulk densities that are as much as an order of magnitude higher than other areas of the Everglades. Thus, when converted to $\mu g \cdot cm^3$ of soil, RWMA soil contains significantly more N and P, respectively than the oligotrophic regions of the WCAs (Koch, 1991; Newman et al., 1997). In the context of bioavailability to plants, this may be a better way to interpret soil nutrient data since roots exist in three dimensional space.

PERIPHYTON

Periphyton development along the transect stations appears to be limited primarily by water availability and secondarily by macrophyte biomass. For example, when standing water was present for a brief period of time at four stations in October, periphyton only existed at the two stations where macrophyte aboveground biomass was the lowest. Furthermore, between these two stations, periphyton biomass was higher where the ratio of above-: below-water macrophyte biomass was lowest. This can be best

explained by light attenuation effects on periphyton productivity (Grimshaw et al., 1998). Periphyton biomass estimates were lower than what has been reported for enriched areas of WCA-2A where the periphyton is inhibited by dense macrophyte cover (McCormick et al., 1998). Tissue P concentrations were approximately twice as high as in interior (oligotrophic) WCA-2A (McCormick and Scinto, 1999, McCormick and Stevenson, 1998; McCormick et al., 1998). Furthermore, elevated concentrations of nitrogen species may influence both periphyton biomass and taxonomic compositions. Productivity data are limited but comparable to estimates obtained during the wet season in interior WCA-2A (McCormick et al., 1998). Although there are limited surface-water data, pH measurements indicate that at pH 6.7 - 6.8, RWMA surface-water is acidic at times which may itself contribute to the absence of well-defined calcium carbonate-based periphyton mats. Periphyton biomass and chlorophyll *a* accumulation on glass slides was very low and similar to growth rates observed in oligotrophic WCA-2A (McCormick and Stevenson, 1998). Currently, no data are available on taxonomic compositions.

MACROPHYTES

Total and aboveground biomass of *Cladium* was lowest at the 0.25 and 0.50 km stations of the southern transect where soil elevations are highest and, consequently, water levels are lowest. *Typha* communities were absent within the vicinity of all southern transect stations except $S_{4.0}$. Specific water depths measured within the sampled macrophyte stands in January 1999 (Table 4) and along the 50 m-line transects (Figures 23a-k) show a strong positive relationship between the dominance of *Typha* vegetation and water depth. Estimates of total aboveground biomass for *Cladium* lie somewhere in

between those reported from non-impacted (unenriched interior marsh) and transitional (semi-enriched) areas of WCA-2A, while *Typha* values were considerably lower (Miao and Sklar, 1998). The percentage of other species (i.e. non-*Cladium* or -*Typha*) in *Cladium* stands averaged 10% which is relatively high compared to 7.2% and 0.1% documented by Miao and Sklar (1998) in impacted and non-impacted sites, respectively. For *Typha* stands in the RWMA, this number rose to 32% which was again much higher than 23% and 7.6% of these same areas in WCA-2A.

Leaf densities of *Cladium* were significantly higher than *Typha* in measurements taken on August 1998. This is likely due to the decline of *Typha* plants relative to *Cladium* (reflected in the number of live-dead leaves) during the 1998 summer drought. Leaf heights, however, remained similar. The biomass and number of non-*Cladium*/*Typha* plants was highest in *Typha* stands and at stations with lower water levels within both *Cladium* and *Typha*. This may be evidence of a response to reduced light limitation in the lower density *Typha* stands (both leaf and plant numbers) and to the lower biomass of both *Typha* and *Cladium* at drier stations.

Although macrophyte biomass and stem densities were not associated with any particular aspect of soil chemistry, tissue concentrations of P in aboveground plant tissues were approximately twice as high in *Typha* as *Cladium*, illustrating the well-known affinity of *Typha* for P. Non-*Cladium*/*Typha* plants also possessed high tissue P compared to *Cladium*. Nitrogen followed no such trends in *Typha* vs. *Cladium* but was somewhat elevated in non-*Cladium/Typha* species. As mentioned previously, levels of nutrients per unit soil volume are high, presumably allowing plants to grow (at least initially) without P limitation.

Highest species diversity recorded during the general survey was observed at $N_{0.50}$ where porewater nutrients where elevated. Among stations, %OBL was positively related to water depth, whereas %FAC was inversely related to water depth. %FACW exhibited variability in this regard. UPL species (data not shown) were restricted to the $N_{0.50}$ station. This would suggest that a shift to OBL species is likely to occur in response to hydropattern restoration. However, it is difficult to speculate on which species of OBL (i.e. *Typha* vs. *Cladium*) will proliferate under such circumstances. Presently, macrophyte biomass and species abundance is highly variable in the RWMA. One reason for this is the heterogeneous nature of the landscape with respect to soil and water depths. As a consequence of overdrainage, fire has played direct (removal of existent vegetation) and indirect (burning of muck layers to create depressions that hold water) roles in shaping the landscape and, therefore, macrophyte communities (Newman et al., 1998; Sasse et al., 1998). The inverse relationship between water and soil depths shown in Figures 24b,e,f,g,i,j may be evidence of how fire affects soil topography and therefore hydrology. During the interim period of rainwater retention (yr.1999-2000) and, eventually (yr. 2000), STA-5 discharge into the RWMA, it is expected that fire events that burn down soil layers will diminish in frequency. As soil nutrients are already present in relatively high amounts (by volume), it would appear that hydrology and water quality characteristics of the discharge itself will be a major factor influencing physical and biological responses of the system.

MODELING

Due to the unique hydrological features of the RWMA, there are not appropriate data to calibrate the net settling rate and the relationship between P accretion and soil accretion rates. Furthermore, there are no clear relationships between soil TP concentration and vegetation type. Consequently, the logistic equation in the EPGM could not be recalibrated. As the system evolves in response to STA discharge and more data become available, the EPGM will be recalibrated for parameters specific to the RWMA.

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Appendix B. List of species found in the RWMA during the general survey (all stations).

Acer rubrum
Andropogon glomeratus
Aster dumosos
Baccaris glomerulifolia
Boehmeria cylindrica
Cirsium nuttallii
Cladium jamaicense
Conoclinium coelestinum
Cyperus distinctus
Cyperus odoratus
Dichromena colorata
Eleocharis baldwinii
Erechitites hieracifolia
Erianthus giganteus
Erigeron quercifolia
Eupatorium capillifolium
Eustachys glauca
Euthamia minor
Hydrocotyl bonariensis
Hydrolea corymbosa
Hypericum brachyphyllum
Hypericum fasciculatum
Hyptis alata
Ipomoea spp.
Juncus marginata
Juncus scirpoidia
Leersia hexandra
Limnomium spongia
Ludwigia leptocarpa
Ludwigia peruviana
Ludwigia repens
Lythrum alatum var. lanceolatum
Mikania scandens
Mitreola petiolata
Myrica cerifera
Oxalis dillennii
Panicum dichotomum
Panicum hemitomon
Panicum ensifolium
Paspalidium geminatum
Peltandra virginica
Pennisetum purpureum
Phyla nodiflora
Pluchea symphytifolia

Pluchea rosea
Polygonum hydropiperoides
Ptilimnium capillaieum
Rorripa teres
Rynchospora corniculata
Rynchospora inundata
Rynchospora microcarpa
Rynchospora tracii
Sagittaria lancifolia
Salix caroliniana
Sarcostemma clausum
Senecio spp.
Setaria geniculata
Setaria magna
Solidago leavenworthii
Solidago stricta
Teucrium canadense
Thelypteris palustris
Typha domengensis

Table 1. Surface-water and porewater measurements (* = constituent analyzed for surface-water only).

Constituent	Abbreviation	units
dissolved oxygen	DO	mg/L
conductivity	COND	uhos/cm
pH	pH	pH units
alkalinity	ALK	mg/L
dissolved organic carbon	DOC	mg/L
total kjeldahl nitrogen	TKN	mg/L
total dissolved kjeldahl nitrogen	TKN-F	mg/L
ammonium	NH_3-F	mg/L
nitrate+nitrite	NOx-F	mg/L
nitrite*	NO_2-F	mg/L
total phosphorus	TP	mg/L
total dissolved phosphorus	TP-F	mg/L
soluble reactive phosphorus	PO4	mg/L
total dissolved potassium	K-F	mg/L
total dissolved silica	SiO_2-F	mg/L
total dissolved iron	Fe-F	µg/L
total dissolved magnesium	Mg-F	mg/L
total dissolved zinc*	Zn-F	µg/L
total dissolved calcium	Ca-F	mg/L
total dissolved copper*	Cu-F	mg/L
total dissolved chloride	Cl-F	mg/L
total dissolved sulfate	SO_4-F	mg/L

Table 2. Approximate locations of 50 m line-transects in the RWMA.

Latitude	Longitude	Corresponding Figure
26 25.561	80 52.392	23a
26 25.561	80 52.392	23b
26 25.145	80 52.094	23c
26 25.145	80 52.094	23d
26 24.462	80 51.268	23e
26 23.423	80 50.586	23f
26 23.500	80 51.955	23g
26 23.500	80 51.955	23h
26 23.500	80 51.955	23i
26 22.721	80 48.406	23j
26 22.721	80 48.406	23k

Table 3. Integrated soil TP concentrations (mg/kg) collected at *Cladium* and *Typha* sites for 0-10 and 0-20 layers

0-10 cm		0-20cm	
Cladium	*Typha*	*Cladium*	*Typha*
434	686	359	537
917	337	703	291
719	341	581	143
429	495	267	362
463		309	
274		231	
224		183	
301		202	
Mean = 470	Mean = 465	Mean = 354	Mean = 333
Median = 431	Median = 418	Median = 288	Median = 327

Table 4. Water depths within specific macrophyte biomass/plant density sampling areas.

Station	macrophyte stand type	water depth (cm)
$N_{0.25}$	short *Cladium*	-14
	tall *Cladium*	-14
$N_{1.0}$	*Cladium*	-14
	Typha	+3
$N_{4.0}$	*Cladium*	+8
	Typha	+15
$S_{0.25}$	*Cladium*	-55
$S_{1.0}$	*Cladium*	-40
$S_{4.0}$	*Cladium*	-8
	Typha	-5

Appendix A. Schematic representation of sampling from and near the station platforms.